

***Induced Seismicity by Injection Associated With Oil & Gas Development:  
A Primer on Technical & Regulatory Considerations Informing  
Risk Management and Mitigation***

This report is developed by the ISIWG members, with input and support from the ISIWG technical advisors, to help better inform all stakeholders and the broad public on technical and regulatory considerations associated with traffic light systems, monitoring systems, information sharing, and the use of ground shaking metric.

It is also intended to summarize the range of approaches that have been used, or are currently being used, in many local regions to manage and mitigate the risks associated with seismicity that may be induced by injection.

This is an informational document, and is not intended to offer recommended rules or regulations. The ISIWG recognizes that management and mitigation of induced seismicity is best considered at the local / regional levels due to the significant variability in local geology and surface conditions (e.g., population density, building conditions, infrastructure, critical facilities, monitoring capabilities, etc.)

## **1.0 Preface**

State oil and gas regulatory agencies and geological surveys have partnered with the Interstate Oil & Gas Compact Commission and Ground Water Protection Council to create a work group that will proactively discuss the possible association between recent seismic events occurring in multiple states and injection wells. State agencies participating in the Induced Seismicity by Injection Work Group collaborate and share science, research, and practical experience to equip the states with the best decision making tools to evaluate the possible connections between seismic events and injection wells, minimize risk, and enhance appropriate readiness when seismic events occur.

## **2.0 Executive Summary**

This section would be 1-2 pages providing concise summary of the major observations and considerations associated with the report.

## **3.0 Purpose and Scope**

This section would be short and describe the specific purpose of the present document and the applicable scope of the present document.

## **4.0 Background & Issue Overview**

This section would summarize key papers and knowledge base on the topic, leveraging the National Academy of Sciences (2012) report, Department of Energy Geothermal Report, USGS reports, and several of the significant events associated with injection induced seismicity.

#### 4.1 The National Academies Report

#### 4.2 The Department of Energy Geothermal Report

#### 4.3 Summary of Other Major / Recent Significant Events from Each State

### 5. Ground Shaking

#### 5.1 Overview

#### 5.2 Understanding the Modified Mercalli Intensity Index

#### 5.3 Understanding Peak Ground Acceleration & Velocity

#### 5.4 Understanding Structural Integrity – What Shaking Levels Cause Concern

#### 5.5 Public Sensitivity & Perception –

- A. What Vibration Levels Cause Alarm

- B. Addressing public concern

#### 5.6 Subsurface Conditions – What Factors Influence Seismic Wave Attenuation

#### 5.7 Ground Motion Prediction & Attenuation Relationships

- A. Shallow Events versus Deep Events

- B. Predictive accuracy / understanding across USA

#### 5.8 Hydraulic Fracturing versus Waste Water Disposal Wells: Differences

#### 5.9 Correlations between Fault Size, Stress Release, and Energy Release

- A. Consider summary of Professor Zoback (Stanford) published data on relationship describing fault patch size to energy release

- B. Consider summary of other published approaches (science-based) for evaluating energy release and ground shaking characteristics

#### 5.10 Correlations between Ground Shaking and Magnitude Measurements

- A. What correlations are readily available

- B. What are the limits of validity

- C. What are possible approaches for developing improved correlations

## **6.0 Information Sharing to Address Risks and Hazards**

### **6.1 Overview**

- A. Understanding Issues of Data Availability (Regulatory, Industry, Stakeholder Perspectives)
- B. Understanding the Issues of Data Compartmentalization (Regulatory, Industry, Stakeholder Perspectives)
- C. Understanding Current Challenges with Subsurface Fault Mapping
- D. Understanding What May Be Considered “Readily Available” Data
- E. Understanding Information Fragmentation
- F. Understanding Information Management Systems & Constraints
- G. Understanding the Nature of Proprietary and Confidential Business Information

### **6.2 Informing a Risk Assessment**

- A. Historical Seismicity Data (hypocenter, event sequence / timing)
- B. Surface Site Characterization
- C. Subsurface Site Characterization
- D. Injection Well Information

### **6.3 Informing a Risk Mitigation Plan**

- A. Options Based on Local Risk Level
- B. Options Based on Local Monitoring Resources

### **6.4 Informing a Causality Evaluation**

- A. 4-D investigation of all of the available data
- B. Identification and characterization of reactivated faults
- C. Hypocenters: accuracy of locations, and temporal evolution
- D. Applications of Gutenberg-Richter relationships
- E. Use of reservoir modeling approaches to evaluate subsurface pressure
- F. Integration of all available data

- G. Establishing and maintaining a monitoring plan
- H. Stakeholder and regulator engagement and collaboration

## **7. Seismic Monitoring: Regional, State, & Local Capabilities**

### **7.1 Summary of Current USGS Monitoring Capabilities**

### **7.2 Summary of IRIS Resources and Capabilities**

### **7.3 Summary of State Resources & Capabilities**

### **7.4 Technical Considerations for Selecting a Broadband Seismic Array**

- A. Magnitude measurements: accuracy & sensitivity
- B. Epicenter & hypocenter location estimates: accuracy & sensitivity

### **7.5 Overview of Typical “Broadband” Seismic Monitoring System**

- A. Technical Specifications
- B. Technical Capabilities & Limitations

### **7.6 Considerations for Leveraging Synergies of Regional, State, & Local Capabilities**

- A. Case Example: Oklahoma
- B. Case Example: Ohio
- C. Case Example: California

### **7.7 Discussion of Potential Models for Implementing, Funding and Operating Future Monitoring Requirements**

## **8. Traffic Light Systems**

### **8.1 Overview**

### **8.2 Performance vs. Prescriptive Approaches**

### **8.3 Considerations for Establishing Thresholds**

- A. Possible Criteria
- B. Pros & Cons Considering Local Conditions and Risk Level

- C. Possibility of Combining Criteria (e.g., Magnitude and Ground Motion Metrics)

## **8.4 Traffic Light Systems: Triggers**

- A. Considerations for “Green” to “Yellow”
- B. Considerations for “Yellow” to “Red”

## **8.5 Traffic Light Systems: Resets**

- A. Considerations for “Red” to “Yellow” to “Green”
- B. Considerations for “Yellow” to “Green”

## **8.5 Examples of Current Approaches**

- A. Case Examples: Ohio
- B. Case Example: Colorado
- C. *Case Example: California Geysers Geothermal*
- D. Case Example: Canada
- E. Case Example: United Kingdom

## **9. Other risk mitigation and response systems**

## **10. Understanding Current Regulatory Approaches**

### **10.1 Waste Disposal**

- A. Examples of currently adopted regulatory approaches
- B. Examples of publicly proposed regulator approaches
- C. US EPA Report Summary

### **10.2 Hydraulic Fracturing**

- A. Examples of currently adopted regulatory approaches
- B. Examples of publicly proposed regulator approaches

## **11. Conclusions**